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The Effect of 5E-FCM Practices on Achievement, Motivation, and Autonomous Learning and Students' Opinions

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Abstract

This study aimed to determine the effect of 5E-Based Flipped Classroom Model (5E-FCM) applications on students' achievement, motivation, and autonomous learning in teaching 6th-grade multiplication with fractions and to determine students' opinions about the applications. The study was based on the embedded design, which is one of the mixed method designs. The study group consisted of 60 sixth-grade students using the convenience sampling method, one of the non-random sampling methods. As data collection tools, the Achievement Test, Motivation Scale, Autonomous Learning Scale, and semi-structured interview form were used. The data obtained were evaluated using t-tests for related and unrelated samples, and descriptive statistics for frequency, percentage, and mean values. As a result of the 5E-FCM teaching applications carried out in the study, it was determined that the post-test achievement mean scores and autonomous learning mean scores were significant in favor of the experimental group; the motivation levels of the experimental group students towards the course after the application were at a high level and increased significantly. Content analysis of students' opinions on 5E-FCM applications revealed that students expressed positive opinions that they had their own learning opportunities in the process and reinforced the subject.

Keywords: 5E-FCM, Achievement, Autonomous Learning, Motivation, Mathematics Teaching

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INTRODUCTION

In a globalizing world, developments and innovations in the field of education are important for the facilitation and quality of teaching. In this new era of change and development, there are certain skills and competencies expected of every individual. The International Society for Technology in Education (ISTE, 2016) has identified the educational technology standards that students should have in the 21st century. Correspondingly, in the Mathematics Curriculum (MoNE, 2018), "digital competence" and "learning to learn" are some of these competencies. "The "learning to learn" competence is expressed as the need for individuals to be responsible for their own learning and to have learner autonomy (Castle, 2008). During the pandemic period, the cultivation of students who take responsibility for their own learning and possess self-directedness has been a significant factor in the successful execution of educational practices that had to be conducted in synchronous, asynchronous, hybrid, and remote formats (Gao and Zhang, 2020; Göksel and Adıgüzel, 2022). Hence, to raise students with autonomous learning skills, it is thought that there is a need for teaching applications that are planned to be student-centered, give the student responsibility for his/her own learning, and allow the student to learn at his/her own pace in the learning process, apart from teacher-centered learning environments. The flipped classroom model (FCM), in which the out-of-class process is entirely student-controlled (Kara, 2016), is a model that has a positive impact on students' autonomous learning (Bursa, 2019).

FCM is a model that helps to create active learning environments, combines the advantages of face-to-face and online environments, and is a blended learning process based on the constructivist approach. (Bolat, 2016; Hwang, Lai & Wang, 2015; Kalafat, 2019).

Without being limited to time and classroom space, learning environments have been moved to any environment where there is access to the Internet (Ünsal, 2010). Blended learning is defined as combining the advantageous aspects of face-to-face learning in the classroom environment and web-based learning (Horton, 2000). The concept of blended learning is a combination of traditional face-to-face teaching applications in which computer-based technologies are the basis and the e-learning model in which the use of technological tools in learning environments is integrated (Osguthorpe & Graham, 2003). Bergman and Sams (2012) first introduced FCM, one of the blended learning models. FCM is a model in which the traditional teaching process is reversed, where students encounter the topic for the first time outside the class, and in-class activities are designed to reinforce the subject (Bergman and Sams, 2012). Traditional coursework aims to teach and learn the subject in the face-to-face in-class process, while the reinforcement of the subject is left to the out-of-class process as homework due to time constraints (Serçemeli, 2016). In contrast to the traditional course process, the students in FCM are asked to examine course materials such as videos and texts outside the face-to-face course, to start the process of knowledge discovery, and to acquire some basic knowledge before starting the face-to-face in-class process. At this point, the aim is to allocate more time for student-centered activities to reinforce the subject in the in-class process (Love, Hodge, Grandgenett, & Swift, 2014). Since the student manages the learning process in the extracurricular process, FCM is an important factor for students to take responsibility for their own learning. The student is at the center of learning in this model where the student takes responsibility for learning and thus learns to construct knowledge (Aziz, 2021). This enables students to acquire a learning culture (Hayırsever & Orhan, 2018). This means that the designed content is prepared in a way to includes interactive learning strategies and organized in a way that is suitable for the student (Bergman, Sams, 2012). The educator is of great importance for the best practice of this student-centered model. Teachers in this model organize the educational materials that students will use in the extracurricular process of FCM, prepare activities and contents that reinforce the subject by taking into account individual differences in the in-class process, and guide students throughout the process. FCM involves the integration of computer-based individual instruction outside the classroom with interactive group activities inside the classroom. In the out-of-class learning component, students access the basic knowledge of the subject from online learning resources prepared by the teacher and begin the process of exploring the subject (Bishop & Verleger, 2013). It is possible to realize the teaching contents of Bloom's taxonomy's recall and comprehension levels in the extracurricular process and to include interactive learning activities in the in-class process (Bergman & Sams, 2009). In FCM, while some of the application steps of Bloom's Taxonomy, comprehension and recall steps take place in the pre-lesson process, the continuation of the application step, analyzing, evaluating, and creating steps take place in the in-lesson process (Brame, 2013; Cunningham, 2017; Lo, 2017; Westermann, 2014). The above-mentioned features of FCM show that the model is based on student-centered learning and constructivist understanding (Aydın & Demirer, 2016; Aziz, 2021; Hwang, Lai, & Wang, 2015). Within this scope, Lo (2017) and Schallert, Lavicza, and Vandervieren (2022) proposed a cyclical model that combines the 5E learning cycle model and FCM. The 5E-based flipped classroom model is a model that integrates the 5E learning cycle model and the flipped classroom model based on the constructivist approach. In this study, the 5E-based inverse face-to-face class model is used and abbreviated as 5E-FCM. In 5E-FCM, the activities and contents belonging to the introduction, exploration, and explanation steps of the 5E learning cycle model are carried out in the out-of-class process of the flipped classroom model, and the activities belonging to the deepening and evaluation steps are carried out in the in-class process of the flipped classroom model (Lo, 2017).

The pre-assessment of prior learning and readiness before the lesson, capturing the student's attention as the entry step of the 5E learning cycle and conducting activities for the exploration phase where the topic is discovered by the student, all occur during the face-to-face pre-class phase of the FCM. Online materials and course content enable the student to explore the subject matter before the face-to-face lesson or to start the discovery process. After this discovery process, students are expected to construct knowledge in their minds and produce informal knowledge. With the explanation step, the informal knowledge produced by the student is transformed into formal knowledge with the necessary explanations and corrections. Since the process of constructing knowledge takes place before the lesson, more time can be allocated to the work done to reinforce the subject and adapt it to new problem situations in the in-class process, contrary to the traditional understanding. Finally, the process and the work done are evaluated (Lo, 2017; Westermann, 2014).

Considering the studies on the flipped classroom model in mathematics education, it is seen that this model has positive effects on students' problem-solving skills (Lo & Hew, 2017), academic achievement (Şahin, Cavlazoğlu, & Zeytuncu, 2015; Wei, Cheng, Chen, Yang, Liu, Dong, Zhal, & Kinshuk, 2020; Yorgancı, 2020; Zengin, 2017), and class participation (Clark, 2015). At the same time, it has been stated that the flipped classroom model provides a more flexible learning environment than traditional learning approaches, which greatly contributes to the development of conceptual understanding in mathematics lessons (Wei et al., 2020).

The flipped classroom model provides a more flexible learning environment than traditional learning approaches due to the development of 21st-century skills and the learner's self-control in the teaching process (Özbay & Sarıca, 2019). In particular, autonomous learning, which is defined as a process in which a learner makes deliberate decisions to take responsibility for goal setting, planning, and taking action in a learning activity and in which the learner is the manager of learning, is an important factor for the success of the learning process (Karataş, 2013; Artsın, Koçdar, & Bozkurt, 2020). It is thought that the flipped classroom model will be effective in developing autonomous learning in terms of imposing more learning responsibility on the student due to its structure. Motivation for learning is an important factor that is effective in the timely fulfillment of students' learning responsibilities in the education and training process (Duman, 2019). It is important to organize teaching environments and practices in a way that is compatible with student characteristics to increase students' motivation (Çukurbaşı, 2016). The flipped classroom model is a frequently used teaching model in terms of its student-centered structure, increasing the active learning process in the classroom (Yılmaz, 2016), increasing student satisfaction (Jensen, Kummer, & Godoy, 2015; Tucker, 2012) and motivation (Alsancak Sırakaya, 2017; Kara, 2016; Yılmaz, 2017) (Yorgancı, 2020). In this context, this study aims to determine the effect of 5E-based flipped classroom model (5E-FCM) applications on students' achievement, motivation, autonomous learning, and students opinions about 5E-FCM applications in teaching 6th-grade multiplication with fractions.

METHOD

Research Model

In the study, since it was aimed to reveal the effect of 5E-FCM applications on 6th-grade middle school students' achievement, motivation, and autonomous learning on multiplication of fractions, and to determine students' views on the process, the study was based on the embedded design, which is one of the mixed method designs (Creswell & Plano-Clark, 2007). In the embedded design, which combines the strengths of qualitative and quantitative designs, data obtained by an alternative method are also needed for the different types of data obtained by the researcher to support, generalize, or explain other data (Creswell & Plano-Clark, 2007). In this study, quantitative data were obtained in accordance with the experimental design with a pre-post-test control group. For the qualitative part of the study, the case study (Yıldırım & Şimşek, 2018), which studies a current phenomenon within a real-life framework and is used when multiple data sources and evidence are available, was utilized. Semi-structured interview technique, one of the qualitative data collection methods, was used to support quantitative data in the study

Study Group

This study was carried out with 60 sixth-grade students who were studying in a public school in the Kilimli district of Zonguldak province in 2022 and who were determined by convenient sampling methods from non-random sampling methods. A pilot study was also conducted with 30 students. 30 students were selected as the control group (47% female, 53% male) and 30 students were selected as the experimental group (40% female, 60% male). Fifth-grade mathematics report card grades of the selected students were examined. The groups were determined by selecting the sections randomly since all groups had similar mathematics course grade point averages and there was no significant difference between the fifth-grade mathematics course achievement grade point averages ($p<.05$).

Data Collection Tools

To examine the effect of 5E-FCM applications on students' achievement in multiplication of fractions, an achievement test consisting of 9 open-ended questions was developed by the researchers. An item pool was created by examining the relevant literature, the curriculum (MoNE, 2018), and the MoNE textbooks in line with the two learning outcomes and the five learning components of the learning outcomes. Five field education experts' opinions were taken to determine the content validity of the test in terms of the questions' suitability to the learning outcome, clarity, and conformity with Turkish spelling rules. Experts agreed that the questions in the pre-test form measured the targeted construct. Accordingly, the scale was finalized. In order to evaluate the comprehensibility of the questions in the achievement pretest scale, it was applied to five seventh-grade students selected from the pilot group. The scale consisting of 9 open-ended questions, which were found to be comprehensible, was finalized. An achievement test was applied to the experimental and control groups as a pre-post test before and after the experiment. To investigate the effect of 5E-FCM applications on students' autonomous learning, the Autonomous Learning Scale developed by Macaskill and Taylor (2010) and adapted into Turkish by Arslan and Yurdakul (2015) was used. The scale has two dimensions, "Independent learning" and "Study habits", and the Cronbach Alpha value was found to be 0.80 (Arslan & Yurdakul, 2015).

In the study, the Motivation Scale, which is a subscale of the "Motivational Strategies for Learning Scale" developed by Pintrich, Smith, Garcia, and McKeachie (1991) and adapted into Turkish by Karadeniz, Büyüköztürk, Akgün, Çakmak, and Demirel (2008), was used to investigate the effect of 5E-FCM applications on students' motivation. Sub-scales can be used separately depending on the purpose of the research (Karadeniz et al., 2008). Within this scope, the Motivation Scale used in the study is a 7-point Likert-type scale consisting of three main components and five sub-dimensions. The Motivation Scale consists of three main factors and a total of five sub-factors. The "value" main component consists of "intrinsic goal orientation" and "task value" factors; the "expectancy" main component consists of "learning control belief" and "self-efficacy perception about learning and performance" factors; and the "affective" main component consists of "test anxiety" factor. The Cronbach Alpha internal consistency coefficient of the scale was found to be .79 (Karadeniz et al., 2008). The Cronbach's alpha values of the factors obtained show that the scale is reliable.

A semi-structured interview form was prepared and applied to obtain the opinions of the experimental group students regarding the 5E-FCM teaching applications. In order to develop the semi-structured interview form, a question pool of 7 items was created as a result of the literature review. Field education experts were consulted to examine the scope, appropriateness, and comprehensibility of the related items. The pre-test interview form was applied to two students in the experimental group to determine the duration and comprehensibility of the application, and the scale was finalized after it was determined that there was no problem with comprehensibility. During a semi-structured interview with 26 volunteer students, the students were asked questions about the difficulties they encountered in the course, the advantages and disadvantages of teaching, and their opinions about 5E-FCM.

Data Analysis

The scores of the participants from the scales were calculated to examine the effect of 5E-FCM applications on students' achievement, motivation, and autonomous learning on multiplication of fractions, and kurtosis and skewness values were examined to determine whether the scores were normally distributed (Tabachnick & Fidell, 2013). Table 1 shows the kurtosis and skewness values obtained from the Achievement Test, Motivation Scale, and Autonomous Learning Scale.

Table 1: Skewness and Kurtosis Values of Achievement Test, MS and ALS Scores

Scale	Group	Group	N	$\bar{X}$	s	Skewness	Kurtosis
Achievement Test	Experimental	Pre-Test	30	1.81	1.79	.753	-.382
		Post-Test	30	6.29	3.24	-.628	-.574
	Control	Pre-Test	30	2.30	1.32	-.255	-.602
		Post-test	30	3.12	2.48	.696	-.070
Motivation Scale	Experimental	Pre-Test	30	3.67	.24	-.218	-.467
		Post-Test	30	4.14	.22	-.175	-.126
	Control	Pre-Test	30	3.85	.55	-.074	-.182
		Post-Test	30	3.65	.50	.034	.717
Autonomous Learning Scale	Experimental	Pre-Test	30	4.36	.93	-.633	.046
		Post-Test	30	5.00	.67	-.763	-.058
	Control	Pre-Test	30	4.39	.37	-.154	-.472
		Post-Test	30	4.30	.32	.097	-.666

According to Tabachnick and Fidell (2013), it is assumed that the data fulfills the normal distribution condition if it is between -1.5 and +1.5. Accordingly, when the values in Table 1 were analyzed, it was determined that the kurtosis and skewness values of the experimental and control groups were between -1.5 and +1.5 in all measurements. In this context, the related and unrelated samples t-test was used for the comparison of normally distributed within-group data. A ranking measurement level can be defined as a ranking measurement level if it can be ranked in terms of having a certain characteristic. Accordingly, the mean ranges for the five-point Likert-type scales and sub-dimensions were accepted as low for 1-2.33, medium for 2.34-3.66, and high for 3.67-5; for the seven-point Likert-type scale, low for 1-2.99, medium for 3-5 and high for 5.01-7. Besides, Cohen's *d* values were calculated to determine the effect size to determine the practical significance of the results obtained in the study (Özsoy & Özsoy, 2013). Cohen's *d* values were interpreted as having a small effect between 0.20 and 0.50, a medium effect between 0.50 and 0.80, and a large effect above 0.80 (Kılıç, 2014). The content analysis method was used to analyze the opinions on 5E-FCM applications. The interviews with the students were recorded to analyze the data obtained from the interview form and then the opinions were coded. The opinions of two field experts were obtained after coding and organizing the themes. The code agreement between the two experts was found to be 90%. According to this ratio, it was determined that the codes and themes were reliable, and direct quotations were also included.

Application Process

After the students were informed about the study, the scales were applied as a pre-post test. Student opinions were obtained through semi-structured interviews after the application. In the control group, following the pre-test applications, instruction was carried out by taking into account the instructions in the Mathematics Curriculum, using the textbook and the teaching activities in EBA (Education Information Network), while in the experimental group, teaching applications designed according to 5E-FCM were carried out. As the flipped classroom model is based on a constructivist foundation (Sağlam, 2016), instruction was designed based on the 5E learning cycle model. The experimental group's lessons were carried out with the lesson plan and teaching activities prepared based on the 5E-FCM model, the structure of which was revealed by Lo (2017). Since it is important to integrate technology into the process while designing instruction for the flipped classroom model, Nearpod was used as the classroom management system and Padlet, Google Sheets, Geogebra, Powtoon, and Zoom web 2.0 tools were used for other applications and activities.

Nearpod classroom management system was used for students to access the course content before the face-to-face class and students were enabled to interact with this Web 2.0 tool. The digital content of the course content created using the Nearpod classroom management system, dynamic geometry software, and web 2.0 tools is presented in Figure 1.

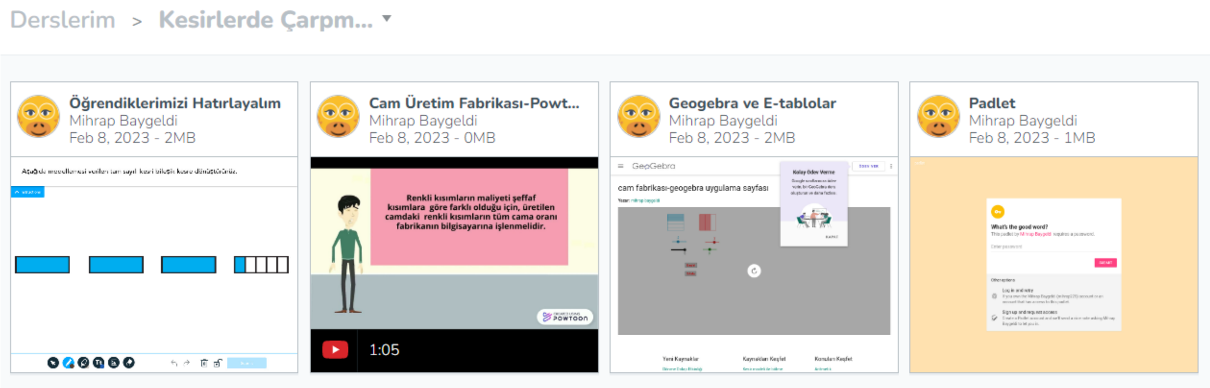

Fig. 1: Nearpod 5E-FCM course process

Figure 1 shows the "Let's Remember What We Learned" activity prepared in the Nearpod classroom management system in the 5E-FCM process to determine whether students are missing prerequisite knowledge, the problem situation named "Glass Production Factory" presented in the introduction step of the 5E learning cycle and created as a digital story, the Geogebra worksheet and guided discovery worksheet used in the exploration step, and the visual of the Padlet page used in the evaluation step of the 5E learning cycle.

With the aim of helping students to establish a relationship between daily life situations and the teaching process, the problem situation presented at the beginning of the teaching process was decided to be transferred to the students using the Powtoon digital story tool. In the teaching applications, teaching activities in which the student is involved in the discovery process were included in accordance with the structure of 5E-FCM and constructivist basis. After the problem situation named Glass Production Factory presented in the introduction step of the 5E learning cycle, Geogebra dynamic geometry software and the accompanying guided discovery worksheet were presented to the students to support the students' discovery process in the discovery step. As students were in the pre-lesson period of the flipped classroom model, the Zoom Web 2.0 tool was utilized in this process in order to keep in touch with peers and to continue teaching with both individual and group work. The students, who accessed basic information about the subject and explored the theoretical part of the subject with the teaching applications carried out before the face-to-face lesson, completed the explanation step of the 5E learning cycle by accessing formal knowledge in the face-to-face environment. The deepening step being in the face-to-face part of the lesson and the theoretical knowledge being comprehended in the pre-lesson process an important factor in giving the necessary time to the teacher and students to reinforce the subject (Burelle-McGivney, Xue; 2013). At this stage of the course, teaching applications prepared using web 2.0 tools were used to reinforce the subject and transfer the learned knowledge to new problem situations. The evaluation section, which is the last step of the 5E learning cycle, was carried out with activities planned to continue both in the face-to-face environment in the classroom and outside the classroom. In the evaluation step, which is important in making the evaluation and ensuring continuity (Öztürk, 2013), homework and activities prepared in accordance with the constructivist approach were presented. The students were asked to construct 3 different problems as a formative assessment tool and this work was organized as a virtual board in the Padlet application. With this virtual board where students can share their problems with their friends, the interaction between students is also increased.

RESULTS

In line with the purpose of the study, a t-test for related samples was used to examine the significance of the difference between the mean achievement test scores of the experimental group in which 5E-FCM was applied and the control group in which 5E-FCM was not applied. The results obtained are given in Table 2.

Table 2: t-test results for the mean pre-post test achievement scores of the students in the experimental and control groups

Group	N	Test	$\bar{X}$	s	$\bar{X}$difference	Sd	t	p
Experimental	30	Pre-test	1.81	1.79	4.48	29	7.83	.000*
		Post-test	6.29	3.24				
Control	30	Pre-test	2.30	1.32	1.02	29	2.04	.050*
		Post-test	3.32	2.48				

*(p<.05)

When Table 2 was examined, it was determined that the mean pre-test achievement score of the students in the experimental group was $\bar{X}$ =1.81 points and the mean post-test achievement score was $\bar{X}$ =6.29 points. It was found that there was a difference of 4.48 points between the experimental group achievement test averages between the pre-post test scores in favor of the post-test within the group, and the t-value was found to be significant in favor of the post-test according to the t-test result for related samples [$t_{(29)}$ =-7.83, p<.05]. This result shows that 5E-FCM teaching applications applied to the experimental group were effective in increasing achievement in favor of the post-test. For the control group, the mean pre-test achievement score was $\bar{X}$=2.30 points, the mean post-test achievement score was $\bar{X}$=3.32, and there was a difference of 1.02 points between the pre-post-test mean scores in favor of the post-test. The t-test result showed that the t-value was borderline significant in favor of the post-test [$t_{(29)}$ =-2.04, p=.05].

Unrelated samples t-test was used to compare the significance of the difference between the mean post-test achievement scores of the experimental and control groups. It was determined that there was a difference of 3.17 points between the experimental and control group achievement post-test mean scores in favor of the experimental group; as a result of the t-test, there was a significant difference between the post-test achievement mean scores in favor of the experimental group [t(58)=4.246, p<.05]. This result reveals that 5E-FCM applications are more effective in increasing achievement than the control group.

To determine the effect of 5E-FCM applications on achievement, the effect size value calculated was η^2=0.23 and Cohen's d=.54. Therefore, it can be said that 23% of the variance of the achievement scores emerged due to 5E-FCM. Furthermore, the difference between the mean scores of the achievement scale is .54 standard deviation. The calculated effect size (η^2=0.23, d=.54) shows that

5E-FCM practices have a medium effect size for the difference between the averages (Kılıç, 2014; Sullivan & Feinn, 2012).

In the study, secondly, a t-test for related samples was applied to examine the significance of the difference between the pre-post test mean scores of the Motivation Scale (MS) of the experimental and control groups. The obtained t-test results are given in Table 3.

Table 3: t-test results for the mean pre-post test Motivation Scale scores of the students in the experimental and control groups

Group	N	Test	$\bar{X}$	s	Sd	t	p
Experimental	30	Pre-test	4.36	.93	29	7.05	.000*
		Post-test	5.00	.67			
Control	30	Pre-test	4.39	.37	29	2.31	.028*
		Post-test	4.30	.32			

(*p<.05)

Table 3 shows that there was a difference of 0.09 points in favor of the pre-test between the pre-test mean score ($\bar{X}$=4.39) and the post-test mean score ($\bar{X}$=4.30) in the control group. According to the results of the related samples t-test conducted to examine the significance of the difference between the pre-post test MS mean scores of the students in the control group, a significant difference was observed in favor of the pre-test in the motivation of the control group students towards the course. This result shows that there is a decrease in the motivation of the control group students towards the lesson as a result of the teaching made in accordance with the current MoNE program within the framework of the multiplication process in fractions. There was a difference of 0.64 points between the pre-test mean score of the Motivation Scale for the experimental group ($\bar{X}$=4.36) and the post-test mean score ($\bar{X}$=5.00). The t-test result for the significance of the obtained difference showed that there was a significant difference in the mean motivation scores in favor of the post-test [t(29)=7.05, p<.05]. Hence, experimental group students' 5E-FCM teaching applications were found to be effective in increasing the motivation level in favor of the post-test. An unrelated samples t-test was applied to compare the post-test MS scores of the experimental and control groups after the teaching applications. When the mean MS scores of the experimental and control groups were examined, it was determined that there was a significant difference between the mean post-test motivation scores in favor of the experimental group according to the t-test result for unrelated samples, which showed a difference of 0.70 points in favor of the experimental group [t(58)=5.191, p<.05].

To determine the extent of the effect of 5E-FCM applications on motivation, the eta-square (η^2) and Cohen's d values, which are effect sizes, were analyzed. The effect size value was calculated as η^2=0.32 and Cohen's d=.67. Therefore, it can be said that 32% of the variance of the achievement scores emerged due to 5E-FCM. Furthermore, the difference between the mean scores of the motivation scale is .67 standard deviation. The calculated effect size (η^2=0.32, d=.61) shows that 5E-FCM practices have a medium effect size for the difference between the averages (Büyüköztürk, 2020; Kılıç, 2014; Sullivan & Feinn, 2012). Table 4 shows the results of the post-test scores of the Motivation Scale for the experimental and control groups and the averages of the sub-dimensions of the scale.

Table 4: Descriptive statistics of the Motivation Scale and its sub-factors of the experimental and control group

Main Components	Factors	f		Minimum		Maximum		Mean ($\bar{X}$)		Standard Deviation (s)	
		Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
Value	Intrinsic goal orientation	30	30	3.25	3.50	6.50	6.00	5.29	4.56	.853	.817
	Task value	30	30	4.00	3.50	6.75	5.75	5.67	4.64	.788	.596
Expectation	Belief in learning control	30	30	3.20	3.40	6.40	5.60	5.32	4.59	.934	.685
	Perception of self-efficacy related to learning and performance	30	30	3.00	3.00	6.50	6.50	5.31	4.73	.942	.989
Affective	Exam anxiety	30	30	1.20	1.60	5.40	4.80	3.81	3.34	1.02	.854
Motivation Total		30	30	3.50	3.65	5.90	4.90	5.00	4.30	.674	.321

Considering the averages presented in Table 4, the control group was found to have a moderate level of motivation according to the scores of intrinsic goal orientation, task value, learning control belief, self-efficacy perception about learning and performance, test anxiety sub-factor, and the overall average of the scale. Considering the mean scores of the experimental group, the scores of intrinsic goal orientation, task value, learning control belief, and self-efficacy perception related to learning and performance showed that the group had a high level of motivation, while the scores of test anxiety and the general average of the scale showed that the group had a high level of motivation. The difference between the mean motivation scores of the experimental and control groups and the difference in the motivation levels of the students depending on the effect size value shows that the 5E-FCM teaching applications applied within the scope of multiplication of fractions in the experimental group were effective in increasing the motivation towards the course compared to the control group.

For the third problem of the study, a paired samples t-test was conducted to examine the significance of the difference between the pre-post test mean scores of the Autonomous Learning Scale (ALS) of the experimental and control groups. The obtained t-test results are given in Table 5.

Table 5: t-test results for the mean pre-post test Autonomous Learning Scale scores of the students in the experimental and control

Group	N	Test	$\bar{X}$	s	Sd	t	p
Experimental	30	Pre-test	3.67	.25	29	7.12	.000*
		Post-test	4.14	.22			
Control	30	Pre-test	3.85	.55	29	1.65	.108
		Post-test	3.65	.50			

(*p<.05)

Table 6 shows that the mean pre-test and post-test scores of the control group were $\bar{X}$=3.85 and $\bar{X}$=3.65 points, respectively. Examining the mean scores of the control group ALS, it was determined that there was a difference of 0.20 points between the pre-post test mean scores in favor of the pre-test and that the mean scores decreased after the application. According to the t-test result, it was determined that there was no significant difference between the pre-post test AL score averages of the control group students [t(29)=1.65, p>.05].

For the experimental group, it is seen that there is a difference of 0.47 points in favor of the post-test between the pre-test $\bar{X}$=3.67 and post-test $\bar{X}$=4.14 mean scores in the pretest and post-test, respectively. According to the results of the t-test, students' autonomous learning mean scores showed a significant difference in favor of the post-test [t(29)=7.12, p<.05]. Based on this result, it shows that the 5E-FCM applications applied to the experimental group students were effective in increasing the level of autonomous learning in favor of the post-test. After the teaching applications, the post-test SCL scores of the experimental and control groups were compared by t-test for unrelated samples, and it was observed that there was a significant difference between the mean post-test motivation scores in favor of the experimental group [t(58)= 4.791, p<.05).

The effect size value of 5E-FCM applications on autonomous learning was calculated as η^2=0.28 and Cohen's d=.62. Therefore, it can be said that 28% of the variance of the achievement scores emerged due to 5E-FCM. Furthermore, the difference between the mean scores of the autonomous learning scale is .62 standard deviation. The calculated effect size (η^2=0.28, d=.62) shows that 5E-FCM practices have a medium effect size for the difference between the averages (Kılıç, 2014; Sullivan & Feinn, 2012). Table 6 shows the results of the post-test scores of the Autonomous Learning Scale and the averages of the sub-dimensions of the scale.

Table 6: Descriptive statistics of the Autonomous Learning Scale and its sub-factors of the experimental and control group students

Factors	f		Minimum		Maximum		Mean ($\bar{X}$)		Standard Deviation (s)	
	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
Independent Learning	30	30	3.57	2.43	4.71	5.00	4.16	3.67	.282	.550
Study Habits	30	30	3.80	2.20	4.60	5.00	4.11	3.64	.255	.539
Autonomous Learning Total	30	30	3.67	2.67	4.58	5.00	4.14	3.65	.224	.505

Table 8 shows that the control group had a moderate level of autonomous learning according to the scores belonging to the independent learning, study habits sub-factor, and the general average of the scale. The experimental group was found to have a high level of autonomous learning according to the scores belonging to the independent learning, study habits sub-factor, and the overall average of the scale. In line with the results obtained, the 5E-FCM teaching applications were effective in increasing the autonomous learning levels compared to the control group.

For the fourth problem of the research, the opinions of the students in the experimental group about the 5E-FCM applications obtained from the semi-structured interview form were subjected to content analysis. Figure 2 shows the categories and codes obtained from the content analysis.

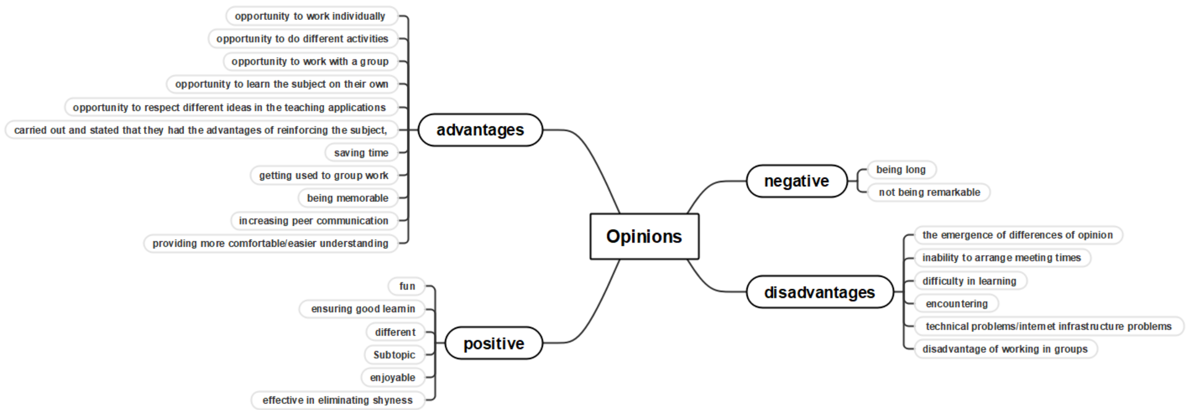

Fig. 2: Codes and themes of student opinions.

Figure 2 shows that 25 codes and 230 opinions were identified under 4 categories according to the results of the content analysis. The analysis showed that the students found the 5E-FCM applications enjoyable, different, and fun, that these studies were effective in eliminating shyness and ensuring good learning, that the mathematics course was more effective in this way, and that they thought it should continue. Accordingly, some of the student opinions in the positive theme are as follows:

S3: Fractions became more enjoyable and it made me feel less ashamed of my friends.

S7: It was different and effective from the math lessons we normally teach.

S11: In this way, it helps to learn the subject better.

S16: I would like math lessons to continue in this way.

Students saw it as an opportunity to find the to work individually, to do different activities, to work with a group, to learn the subject on their own, to respect different ideas in the teaching applications carried out and stated that they had the advantages of reinforcing the subject, saving time, getting used to group work, being memorable, increasing peer communication, and providing more comfortable/easier understanding. Sample student opinions belonging to the advantage category are as follows:

T23: It provided the opportunity to do group work and learn the subject on their own.

S2: With this method, we reinforce the subject while learning it. This allows us to save time.

S19: We respected each other's opinions with group unity and had a lot of fun.

S20: In my opinion, math lessons should be spent with different activities (models, presentations, small experiments, etc.) instead of tests.

Besides, a few of the students had negative opinions about 5E-FCM applications in terms of the process being long and not being remarkable. Some opinions that students see as disadvantages were also identified. Group work is seen as an advantage for some students and a disadvantage for others. However, the emergence of differences of opinion, disadvantage of working in groups, inability to arrange meeting times, difficulty in learning, and encountering technical problems/internet infrastructure problems are the opinions collected under the disadvantage theme. Some of these opinions are as follows:

S25: In online courses, sometimes the internet connection may be interrupted and there is no sound or image.

S14: It is a bit more difficult to learn with the flipped classroom model, but this way I can remember more about the subject.

S7: Since we were working in a group, there were differences of opinion, which was a disadvantage for us.

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

In this study, it was examined the effect of 5E-FCM applications on 6th-grade students' achievement, motivation for learning, and autonomous learning in teaching multiplication of fractions. According to the results obtained from the study, it was concluded that the mean post-test achievement scores of the experimental and control groups were significant in favor of the experimental group and that 5E-FCM applications had a moderate effect on increasing student achievement. This result is similar to the studies conducted by Arslan (2021) and Gökdaş and Gürsoy (2018). Arslan (2021) concluded that the flipped classroom model increased students' achievement in teaching the 5th grade fractions and operations in fractions units. Aşıksoy and Ozdamli (2017) concluded in their study that the flipped classroom model based on the 5E learning cycle model has a significantly high effect on increasing student achievement in physics courses. In similar studies, it was stated that the flipped classroom model was effective in increasing student achievement (Alkaya Karagöl, 2020; Alper & Öztürk, 2019; Alsancak Sırakaya, 2015; Bursa, 2019; Şahin, Cavlazoğlu, & Zeytuncu, 2015; Zengin, 2015; Wei, Cheng, Chen, Yang, Liu, Dong, Zhal, & Kinshuk, 2020).

In the analysis made in terms of the post-test MS mean scores of the experimental and control groups, a significant difference was found in favor of the experimental group and it was determined that the experimental group students had a high level of motivation after the application. The results showed that 5E-FCM applications had a moderate effect on increasing students' motivation towards the course. Similarly, in the study conducted by Yorgancı (2020), it was concluded that teaching prepared with activities based on the flipped classroom model to increase student performance in mathematics lessons increased students' motivation. Matsumoto (2016) also found that the flipped classroom model based on gamification was effective in increasing students' motivation. A review of the literature shows that the flipped classroom model is effective in increasing student motivation in many studies (Çukurbaşı, 2016; Girgin & Cabaroğlu, 2021; Gökdaş & Gürsoy, 2018); Lai & Foon, 2019; Kömeç, 2018). Unlike the findings obtained, Duman (2019) stated that the application of the flipped classroom model based on activity-based learning did not cause an effective change in students' motivation.

The mean scores of the experimental group pre-post-test ALS scores were found to be significant in favor of the post-test and it was determined that the experimental group students had a high level of autonomous learning according to the post-test mean scores. It was concluded that 5E-FCM teaching applications had a moderate effect on increasing the level of autonomous learning. Other similar studies show that the flipped classroom model has a positive effect on students' autonomous learning (Alper & Öztürk, 2019; Darıyemez, 2020; Dinçer 2020; Han, 2015; Öztürk, 2016; Shehata, 2019). Differently, Taşçi (2021) concluded in his study that EBA-supported flipped classroom practice did not create a significant difference between autonomous learning skills.

In the study, students had positive opinions about 5E-FCM applications, and it was concluded that the applications were different from other courses, were fun and attracted students' attention, and offered advantages such as increasing peer communication, respecting different ideas, and learning how to work as a team. Moreover, it is among the opinions obtained that it has advantages such as saving time, getting used to group work, and increasing the memorability of the subject. However, it was also stated in the student opinions that there were disadvantages such as sometimes encountering technical problems in the use of technology-based contents of 5E-FCM and not being able to manage differences of opinion due to the fact that students were left to themselves in some parts of the teaching process. According to Çay (2020), students' opinions on flipped classroom model applications were examined and it was determined that students experienced a more interactive teaching process at their own learning pace and that they saved time and participated more in the classroom.

In studies based on the flipped classroom model, group work is used as a dominant learning strategy (Koh, 2019). Strengthening the bonds between students, and increasing satisfaction and motivation are among the reasons for using cooperative learning strategies in flipped classrooms (Umar & Ko, 2022). Nevertheless, students' transition from social to academic relationships is not a natural process and there is a need for students' group work processes to be shaped within a constructivist framework (McCollum, Fleming, Plotnikoff, & Skagen, 2017). Within this scope, the effects of collaborative learning strategies on learning and motivation based on the flipped classroom model are recommended to be investigated in future studies. It is among the data obtained from the study that the flipped classroom model increases student motivation. Studies have also shown that materials presented to students and well-defined tasks motivate students (Campos-Mesa, Castañeda-Vázquez, DelCastillo-Andrés and González-Campos, 2022). Within this scope, it is possible to examine the effects of flipped classroom model applications using course materials supported by Web 2.0 tools on motivation. This study was limited to the 6th grade "Operations with Fractions" sub-learning area. The flipped classroom model can be applied in different learning areas. It is also recommended to conduct new studies by taking into account different age and gender groups.

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